Suppression of vehicle interference for mobile radio operation

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Introduction

In the normal operation of many items of motor vehicle electrical equipment, energy is generated which can be distributed over a wide range of frequencies; this energy being recognized in a receiver as interference or radio noise. While modern amateur mobile radio equipment is usually of advanced design, with the necessary high orders of sensitivity, it can still be affected by radio interference generated by motor vehicle equipment. It is the purpose of this article to describe some of the methods that can be adopted to reduce this interference to tolerable levels.

Depending on the interest of the individual, an amateur mobile radio unit operates in one of the frequency ranges 3·5—30MHz (hf band), 70—145MHz (vhf band) or 432MHz and higher (uhf band); the majority of the units being based on a.m., fm or ssb modulation modes. Because of the many transceivers, transmitters and receivers available, it is not possible in this article to refer to them by individual type number. However, when one or more radio units employing a.m., fm or ssb modulation modes are installed on a vehicle, the suppression requirements for a particular item of electrical equipment are very much the same.

The various forms of suppressor and simple arrangements described in this article have been employed extensively to suppress mf, hf and vhf interference on vehicles fitted with commercial or amateur radio equipment and have given satisfactory performance. Interference to uhf reception is not often encountered, but where this occurs adequate suppression can usually be obtained by fitting suppressors designed for operation in the range 30-400MHz. Military and similar radio installations demand a higher standard of suppression over a wider frequency range than commercial or amateur radio equipment and are usually the subject of individual design exercises.

Typical sources of interference

Abrupt changes or interruptions in the flow of direct or alternating currents occur in the normal operation of many items of vehicle electrical equipment, and it is the transient currents and associated electromagnetic fields arising from these changes or interruptions that cause radio interference.

The continuously generated transients constitute the most annoying sources of interference. Such transients are usually associated with the ignition system; machines having commutators or slip-ring brush gear such as dc generators, alternators, windscreen wiper motors and fan motors; voltage and current regulators, instrument voltage stabilizers and electric petrol pumps. In addition, semiconductor devices such as silicon diodes and transistors must not be overlooked since they perform functions similar to switches or vibrating contacts and are thus liable to create radio interference. These devices are used in automobile alternators, electrical output control units and electronic ignition systems.

On a petrol-engined vehicle the major source of interference is the ignition system. Energy is stored in the ignition secondary circuit capacitance (50-100pF) which is charged to a voltage in the region of 10-25kV. Each time a plug and distributor spark gap breaks down, this energy discharges in an oscillatory manner as a result of resonance between the secondary circuit capacitance of the ignition system (including spark plug, distribution cables and distributor) and the attached lead inductances. The magnitude of these oscillatory currents, which may attain peak values of 200A or more and flow for a few milliseconds, results in electromagnetic fields being set up which can cause serious interference to radio communication systems over a wide frequency range. The rf energy is radiated from the ht circuit and from the lt wiring due to mutual and direct coupling with the ht system. In a typical saloon vehicle the interference amplitude increases with frequency to a maximum in the region of 40-100MHz and then reduces with increasing frequency, although it may remain seriously appreciable up to at least 600MHz. If copper-cored ignition distribution cables are employed, then the interference field in the hf and vhf bands at a distance of 10m from the vehicle would be of the order 800-1,000μV/m: this value can readily exceed the field value set up by many radio transmitters.

Electric motors and generator control units are further items of vehicle equipment which left unsuppressed can produce appreciable interference fields at a distance from the vehicle. Consequently, they can often be troublesome to radio equipment on the vehicle or on other vehicles in close proximity.

In addition to the item of equipment which forms the source of radio interference, the magnitude of the field radiated from a motor vehicle depends on several other factors, for example the length and positioning of the vehicle wiring. Also, the screening effect of the vehicle body can have a pronounced influence. Its effectiveness is extremely variable and unpredictable, however, since it depends on the manner in which the various metal panels are joined and the nature of the joint. This in turn depends on how well the joints are welded; or if they are bolted, on the number and position of the bolts, whether serrated washers are used, and how much insulation in the form of paint is included in the joint. The effectiveness of the body as an electrical shield also varies over the rf spectrum due to resonances which can be set up within the panels. For example, the hinged bonnet of a typical saloon vehicle can resonate in the frequency range 80-120MHz, and if not effectively earthed (or bonded) will radiate interference which may cause serious problems to the reception of vhf signals.

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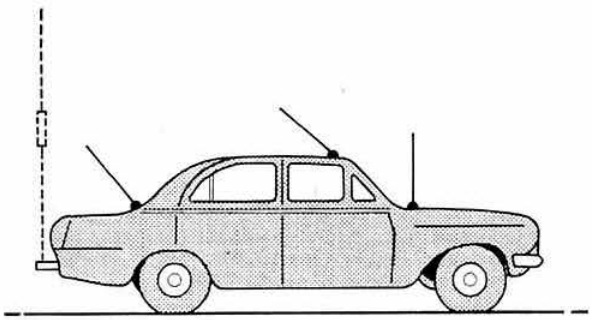

Fig 1. Alternative fixing positions for vhf aerial, and hf aerial position (shown dotted)

Radio frequency interference associated with the electrical equipment on a vehicle can be introduced into a receiver in a number of ways. The most important of these can be summarized as follows:

(a) By direct radiation from the electrical equipment to the radio aerial.
(b) By conduction along the wiring from the equipment to the supply lead of the radio receiver or its power supply.
(c) By conduction along the vehicle wiring and then by radiation to the receiver aerial.
(d) By radiation to mechanical devices such as control cables, rods, wires, tubes (exhaust pipe) which are not associated with the electrical system but located in close proximity to it, and then by re-radiation to the receiver aerial.
(e) By direct radiation from the vehicle wiring to the radio receiver circuits when receiver screening is inadequate.

Thus in any vehicle installation, apart from there being more than one source of interference which can create annoyance, an interference signal can arrive at the receiver by a number of different routes.

Other sources of radio interference received via the vehicle aerial which are worthy of mention, but beyond the scope of this article to discuss at length, are overhead electrical transmission lines, some underground cables, neon signs, electrical equipment in factory areas, trolley-buses and some older vehicles with inadequate suppression schemes. While radio interference from these sources may be annoying to radio equipment users, it is usually only of a temporary nature in a moving vehicle. It is important to ensure that none of these sources is responsible for interference at locations where an attempt is being made to diagnose vehicle equipment as the source of radio interference.

Control by legislation of radiated interference from vehicles

The matter of radiated interference from motor vehicles has been studied in many countries, and national and international legal standards now exist which place maximum permitted limits on the radiated field. These mandatory standards, however, relate only to radiated interference from ignition systems—the major source of interference.

Early legislation varied from country to country. In the UK the first legislation regarding the suppression requirements to be met by motor manufacturers was based on British Standard BS 833: 1953, which was implemented in part in Statutory Instrument No 2023 (1953) of the Wireless Telegraphy Act of 1949. BS 833: 1953 was aimed at limiting radiated interference having frequencies which affected medium and long-wave domestic radio reception, short-wave communications, and television reception in Band 1 (40-70MHz).

In 1964 a common international standard was recommended by a group of experts comprising a working party of the Comité International Spécial des Perturbations Radioelectriques (CISPR). The technical recommendations of the standard (CISPR Recommendation No 18) were later adopted by Working Party 29 set up under the auspices of the UN Economic Commission for Europe to study constructional aspects of motor vehicles. As a result Regulation No 10 of the ECE, namely "Uniform provisions concerning the approval of vehicles with regard to radio interference suppression", was issued in December 1968. The equivalent European Economic Community Directive is EEC 72/245.

The technical standards of ECE Regulation No 10 have now been implemented by many countries, for example all the EEC countries, plus Spain, Sweden and Czechoslovakia etc. In the UK the British Standards Institution has issued an updated standard (BS 833: 1970) which, unlike the previous standard, includes recommendations for achieving the specified new limits. New legislation (Statutory Instrument No 1271: 1973) based on the new British Standard has also been instituted, and became mandatory in April 1974.

The new limits of radiated interference from ignition systems are based on quasi-peak measurements at 10m distance from the source and are as follows:

(i) 50μV/m in the range 40-75MHz.
(ii) 50μV/m at 75MHz increasing linearly with frequency to 120μV/m at 250MHz.

Item (ii) covers the limitation of radio interference frequencies likely to cause annoyance to reception of domestic vhf radio in Band 2, and Band 3 television. This represents an extension of the previous legislation in force in the UK under the Wireless Telegraphy Act 1949 which only specified interference limits up to 70MHz.

In addition to a vehicle manufacturer having to comply with the above limits, owners of vehicles purchased since the new legislation came into force must by law maintain the same ex-works standards of suppression.

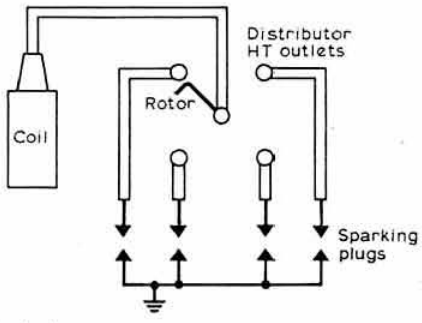

Fig 2. Typical arrangement for high voltage ignition suppression using resistive or inductively wound cables

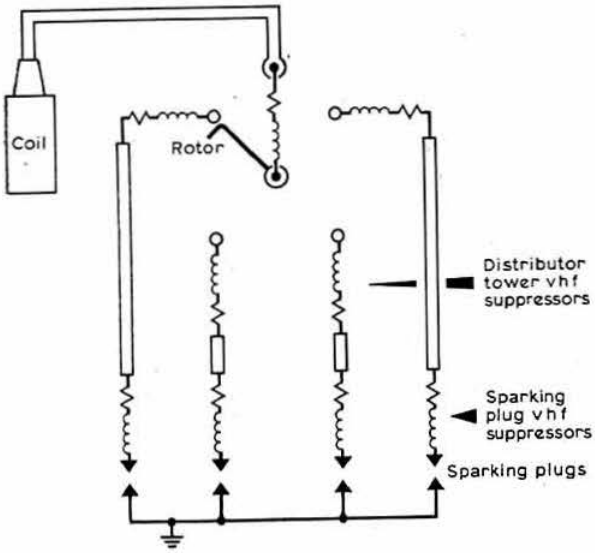

Fig 3. Typical arrangement for improved suppression at vhf using wire-wound resistors and resistive cable

A prototype sampling technique and production conformity tests based on an 80 per cent confidence level ensure that the performance of ignition suppression equipment fitted to 80 per cent of a vehicle manufacturer's production is consistent and complies with the legal requirements. These procedures, which have been employed in the UK since 1970, together with the knowledge gained from the batch sampling techniques of measurement used for the previous 17 years, have provided greater understanding of the pattern of interference from vehicle ignition systems and the subjective effects on radio communication.

Reception of hf and vhf communication signals in vehicles

In its simplest form a commercial or amateur vhf communication system may consist of a single fixed base station and a number of associated mobile units operating in a fairly well defined service area; for example, a private mobile radio service or an amateur Raynet system.

Four frequency ranges are allocated to commercial communication, low-band 71·5-88MHz, mid-bands 105-108MHz and 131-141MHz, and high-band 156-173MHz. In addition there are special Home Office frequency allocations for the police service in the range 94-100MHz. Two frequency ranges (70·025-70·7MHz and 144-146MHz) are in common use in the amateur service.

All modern commercial units, such as those used by taxi and ambulance services, are essentially narrow-band voice communication equipments employing amplitude or phase (angle) modulation and comply with the 12·5kHz channel spacing requirements of the Post Office Specifications W6770 and W6771. Modern amateur units may employ a bandwidth of as little as 2·4kHz, approximately half the bandwidth of commercial systems. SSB is used extensively as well as a.m. and fm. Both commercial and amateur vhf communication receivers have high orders of sensitivity and incorporate either variable frequency or quartz-crystal control of the operating frequency, and agc of certain amplifier stages. Provision is thereby made in the receiver design for likely variations in the received signal strength, due to the screening effect of hills and some types of building, encountered within the transmitter service area. This phenomenon can have a direct bearing on the minimum interference suppression required.

Amateur hf band equipment, for example ssb transceivers, differs considerably from its vhf counterparts in that intercontinental and world-wide communication is possible direct from the vehicle installation. Long-distance communication is carried by ionospheric reflection so that the service area of a mobile unit cannot be predicted as for vhf units. Five frequency ranges are used by the amateur service between frequencies 3·5MHz and 30MHz. A further lower frequency allocation (1·8-2MHz) is sometimes used for local mobile work.

Normal practice with fixed and mobile commercial vhf stations is to use vertical polarization for transmission and reception. With regard to hf and vhf amateur communication systems, however, the majority of the higher power fixed transmitters employ horizontally polarized aerials. Thus, when mobile installations employing vertical aerials are in contact with such fixed stations, cross-polarization of signals occurs. This can result in a wide variation in the received signal strength even within the expected service area of the transmitter. While quite satisfactory reception in a vehicle is still possible under these conditions (hf reception being less affected than vhf) where a weak radio field is encountered, interference from electrical equipment can cause considerable annoyance unless suitable suppression measures are adopted. Obviously reception would be improved and the necessary degree of suppression reduced if the fixed transmitter aerial was vertically polarized; or, in the case of vhf systems, the mobile aerial was of the slant type (ie mounted at 45° to the horizontal).

While a vhf aerial on a vehicle is usually sited on either a rear wing or the roof, an hf aerial, because of its larger physical size, is invariably sited at the rear of the vehicle (Fig 1). Normally this will mean the aerial is well away from the engine compartment and the ignition system, but in the vicinity of such secondary sources of interference as the wiring system to the rear lamp assemblies and the rear section of the exhaust pipe.

For vhf mobile installations, $\lambda/4$ aerials are easily adjusted to be resonant at the operating frequency of the associated communication equipment. HF aerials are constructed from light-gauge tubing with a tuning or loading coil arrangement either in the centre or at the base of the aerial to produce a $\lambda/4$ resonant system at the frequency of operation.

In general the susceptibility of a communication receiver to interference noise, and thus the degree of suppression required, increases with distance from the transmitter.

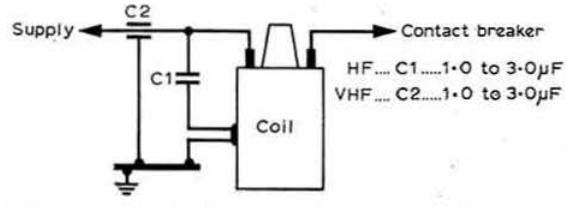

Fig 4. Arrangement of shunt and feedthrough vhf capacitors for ignition coil primary circuit

When operating in regions of high radio field strength, the sensitivity or gain of a receiver will automatically be reduced through its design and interference suppression requirements will be minimal. Nevertheless, when fitting radio communication apparatus to standard production vehicles for operation under such conditions, all possible sources of radio interference still have to be investigated: a standard production vehicle has only its ignition system suppressed and that only sufficient to meet the legal limits established for the protection of domestic radio and television, and communication equipment not associated with vehicles. Thus, when radio communication equipment is installed on a vehicle, additional radio interference suppression is usually required, particularly when the equipment is to be operated in areas of weak radio field strength.

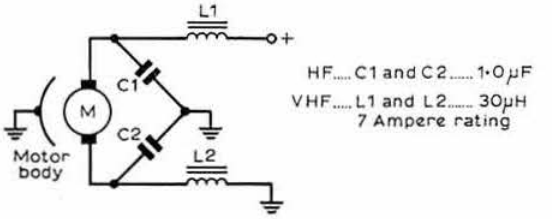

Fig 5. PM fan motor, electric pi pump motor

While, in general, suppression requirements for reception of hf and narrowband vhf communication signals on vehicles are easier to satisfy than those for reception of vhf radio broadcasts, they are more difficult to meet at an acceptable cost than those necessary to receive long and medium wave radio broadcasts. Practically all items of electrical equipment on a vehicle capable of causing interference will need some suppression to receive hf and vhf communication signals, whereas screen wipers, fan motors, voltage regulators and instrument voltage stabilizers etc, need only occasional suppression for reception of lower radio broadcast frequencies. Suitable radio interference suppression schemes for operation of mobile hf and/or vhf communication equipment are shown in Figs 2-13 and in the table.

General principles of radio interference suppression

When mobile radio equipment is installed in a vehicle, consideration must be given to the siting of the equipment and to the suppression requirements of each part of the vehicle electrical system, so that little or no interference is generated within the frequency range of the radio equipment.

The siting of the radio aerial and the routing of the feeder cable should be studied so that as far as possible they are clear of known sources of interference such as ignition and

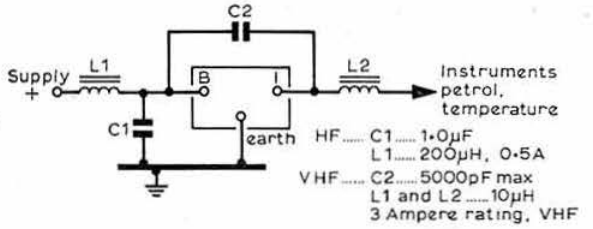

Fig 6. Instrument voltage stabilizer

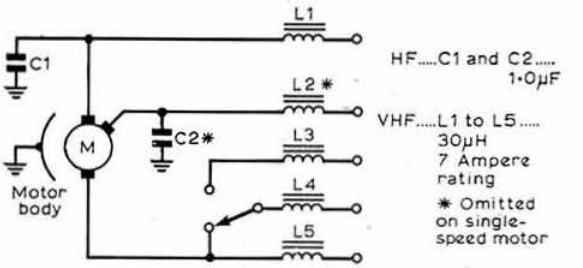

Fig 7. PM screen wiper, 2-speed with regenerative braking

generator circuits and long cable runs in the vehicle wiring harness.

A good earth bond of the feeder cable screen direct to the vehicle chassis at the aerial base is important. Usually, poor feeder cable bonding at this point results in interference to the receiver from most items of ancillary equipment (starter, direction indicators, wind-screen wipers, horns etc). Salt corrosion of earthing bonds can also be responsible for similar interference problems if the vehicle has been in use for some time during adverse winter weather conditions.

It is vital that amateur mobile equipment is installed in accordance with any instructions supplied by the manufacturer, particularly with regard to receiver position and earthing to the vehicle chassis. An unsatisfactory installation in respect of high frequency circulating currents set up by poor earthing connections, high impedance supply lines to the equipment, and the use of inferior aerial feeder cable with poor screening can create many problems when undertaking interference suppression. With correctly installed equipment on the other hand, it is very much easier to identify each source of radio interference and determine how the interference reaches the equipment.

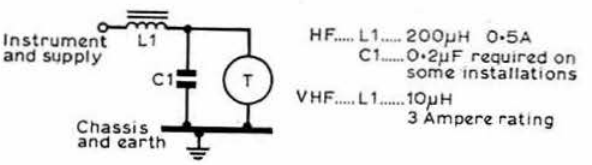

Fig 8. Oil pressure transducer

In general the aim is to reduce interference from each offending item of electrical equipment through the fitting of suitable suppression components, so that the ratio of signal to interference at the receiver is better than 30dB (approximately 30:1). Suppression components vary considerably in their characteristics, and consist of resistive, inductive and/or capacitive elements. Each of these elements is employed in a different manner to obtain the desired interference suppression, and each is of such a value that optimum performance of the suppression component occurs in one of the two frequency ranges 0·15-30MHz and 30-400MHz.

For example, resistive or inductive suppressors having high ohmic values are inserted into ignition plug leads (Figs 2 and 3) to attenuate the high frequency transient currents responsible for interference. Such a suppressor will have little or no effect on the ignition function. On the other hand, where electrical circuits conduct heavier currents (eg battery charging systems) the introduction of such high

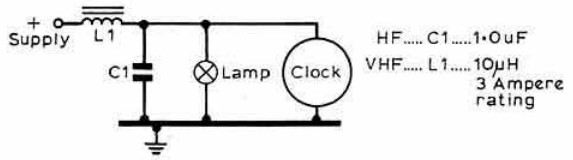

Fig 9. Clock

resistance would be unacceptable. Instead, low resistance inductors constructed on iron cores are used, designed to present a high impedance to either low frequency currents (for example, due to alternator ripple) or radio frequency currents which otherwise would flow into the vehicle's wiring system or radio equipment.

The capacitor presents a low impedance path to high frequency currents and is of great value in restricting their flow to small non-radiating circuits (Fig 4).

Circuits giving high attenuation of radio interference over certain frequency ranges can be constructed utilizing the characteristics of resistive, inductive and capacitive suppressors. These circuits are known as rf filters, examples of which are shown in Figs 5, 6, 7, 8 and 14.

When selecting such suppression components as inductors wound on ferrite cores, the current rating of the equipment to be suppressed is a guide to the size of suppressor required. Many of the commercially available inductors designed to be resonant at vhf communication frequencies, however, may have a greater current rating than that of the equipment with which it is intended to operate. Such suppressors produce an attenuation of interference of some 30dB when mounted close to the terminals of the offending equipment (Figs 5-9).

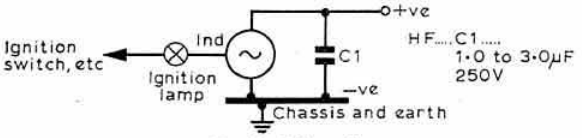

Fig 10. Alternator

The complexity of suppression components and their arrangements will depend upon the interference frequencies, the magnitude of the interference and the lowest value of radio signal which the receiving equipment can be expected to resolve. *It must always be ascertained that the suppression component does not impair the function of the equipment or circuit to which it is fitted.*

Any suppression components that have to be fitted in addition to the standard suppression parts already installed by the car manufacturer represent an increase in the cost of the overall radio installation. Thus the cost of the extra components has to be correlated with the degree of suppression obtained and the performance requirements for the radio equipment.

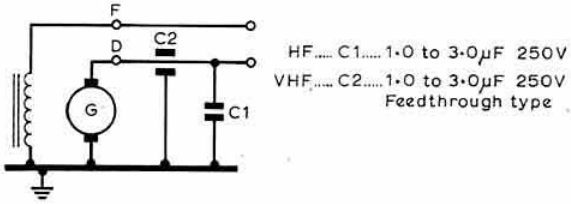

Fig 11. Dynamo

Methods of interference suppression

There will be few installations where the level of interference from certain items of electrical equipment will not warrant the fitting of suppression components. Moreover, these installations cannot be predicted with any certainty as conditions may vary between vehicles of a particular model.

The more involved suppression problems arise when the radio receiver is subjected to interference from several sources; for example, interference from the ignition system may be heard simultaneously with that from the screen-wiper and the instrument voltage stabilizer. In such cases it is usual to adopt a separate suppression scheme for each item of equipment, starting with the equipment which is the source of interference having the highest amplitude. It is usually possible to arrange for most electrical equipment to be disconnected while assessing the suppression required by the ignition system; afterwards each piece of equipment is separately reconnected to the supply for individual assessment.

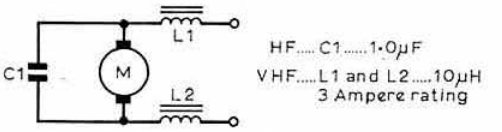

Fig 12. PM electric screen washer

A reliable indication of the effectiveness of each suppression scheme can be made by detuning the main receiver to the upper or lower sidebands of the received signal to an extent where some considerable distortion occurs in the loudspeaker. When detuning is not possible, some indication of the suppression level achieved can usually be made by manually switching out the audio muting circuit and advancing the volume control toward maximum.

A reliable assessment of the effectiveness of supply line filtering can be made by substituting the aerial with a dummy one inserted into the radio receiver aerial socket, and turning the audio gain control to near maximum. Some receiver supply line filters may need to be improved by fitting either an inductor and possibly a capacitor, or a pi-section filter (Fig 13) outboard of the receiver but close to the supply inlet terminal. Supply line filter components should not be mounted within the receiver housing unless they are adequately screened from other components and circuits in the receiver.

Ignition system

In some instances the amount of built-in suppression may be adequate for reception of hf and vhf signals in the vehicle, but this depends on how well the vehicle bodywork is assembled to form an electrical screen around the ignition circuits. However, experience shows that more often than not the

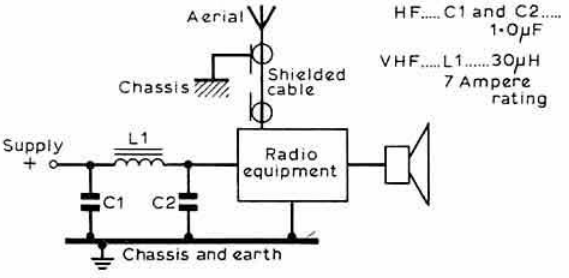

Fig 13. Radio equipment

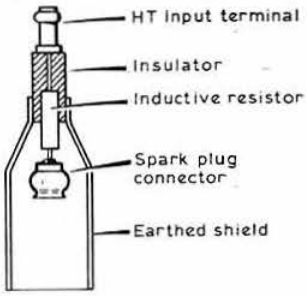

Fig 14. Sparking plug suppressor for vhf applications

ex-works level of suppression needs to be improved, particularly where weaker hf and vhf signals are encountered.

Most vehicle manufacturers fit as initial equipment a resistive-type cable with distributed capacitance which operates as an RC filter network to produce a high attenuation of rf oscillatory currents. Fig 15 shows resistive suppression cable to have a rising impedance characteristic with increasing frequency. This can be compared with the impedance characteristic of the lumped composite carbon type of suppressor, also shown in Fig 15, which falls with increasing frequency above 40MHz. It follows that this latter suppression component, usually made in the form of spark plug "elbow" units and distributor "plug-in" or "screw-in" units, is generally unsatisfactory for suppressing vhf and any uhf interference, but can be useful on the hf bands.

Inductively-wound resistors assembled into screened units for sparking plugs (Fig 14) and "push-in" units for distributor ht outlets (Fig 16) are further types of ignition suppressors. The impedance characteristics of these types is also shown in Fig 15. It will be seen that they give maximum attenuation of interference in the vhf broadcast frequency range, and adequate protection for frequencies up to approximately 300MHz. If suppression units of this design are used in conjunction with resistive cables, the arrangement exhibits wide-band attenuation characteristics of interference frequencies in the long-wave, medium-wave, hf and vhf bands. If

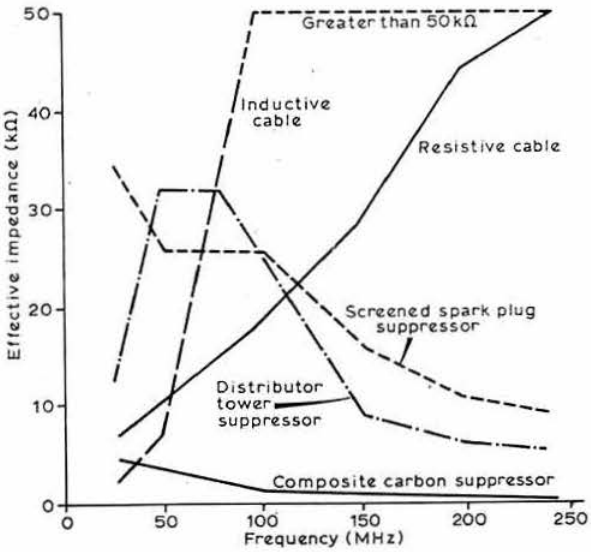

Fig 15. Comparison of suppressor impedance values

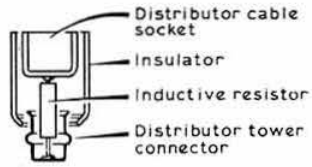

Fig 16. Distributor spark suppressor for vhf applications

copper-cored ignition cable is employed instead of the resistive type, a less effective result is obtained, although in most instances the vehicle will meet regulation standards at frequencies of 40-250MHz.

On no account should the lumped composite carbon-type suppressors be used with copper-cored ignition cable because their effective impedance reduces with increasing frequency. In some cases the radiated ignition interference from the vehicle will meet mandatory requirements (ie ECE Regulation No 10), but it is more usual for the specified limits at 90MHz and above to be exceeded. Also, the increase in radiation generally creates added problems for the satisfactory installation of hf, vhf and uhf radio communication equipment on the vehicle.

A common fallacy which exists in the motor vehicle service trade is that the increased ht resistance resulting from the use of resistive cables, and/or the insertion of suppressors in resistive cables, produces a deterioration in the performance of the ignition system and hence in that of the engine. Consequently, it is not uncommon to find that the manufacturer's original equipment has been replaced with copper-cored ignition cable. Such practice raises the level of radiated interference from the vehicle concerned and infringes the law.

It is often found that ignition interference is evident even when suitable suppression methods are applied to ignition sparking plugs and their connecting leads. In many vehicles this can be shown to be due to radiation from the distributor on account of the jump-gaps between the rotor arm and outlet tower electrodes. This problem can be overcome by the use of a cylindrical metal shield (eg tinplate) which surrounds the distributor cap, and extends to about 0·5in above the top of the outlet towers. This shield must be earthed to the distributor base plate.

The inductively-wound distribution cable and the suppressed distributor rotor arm used on some European production vehicles are worthy of mention. The inductively-wound resistive distribution cable is characterized by its low resistance (200-1,000Ω/ft and by its high impedance at frequencies of 30-300MHz (Fig 15). The cable has therefore

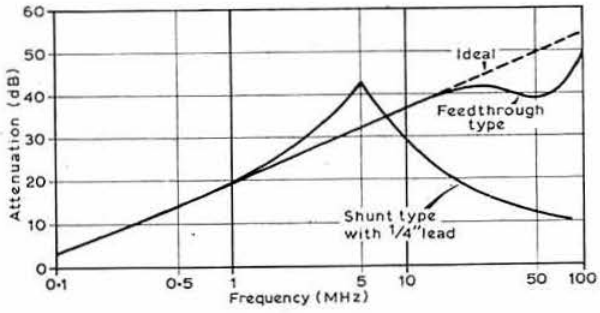

Fig 17. Suppression capacitor frequency characteristics

Summary of equipment recommended for suppression of hf and vhf radio interference

Equipment to be suppressed	Suppression components Up to 30MHz	30-400MHz	Comments
Ignition system			
HT cables (coil-distributor and distributor-sparking plugs)	Resistive core ht cable (Fig 2)	Resistive core ht cable (Fig 3)	Standard fitting on most production vehicles.
Sparking plugs		Screened plug—suppressor (Fig 3)	Screened wirewound resistor (Fig 14).
Distributor ht towers		Unscreened distributor suppressor (Fig 3)	Unscreened wirewound resistor (Fig 16).
Distributor ht cover		Metallic shield (if required)	A cylindrical metallic shield mounted to surround the distributor cap. It is attached to the metallic body of the distributor.
Ignition coil supply terminal ("SW" or "+")	Suppression capacitor 1μF 250V dc wkg (Fig 4)	None usually required: otherwise feedthrough suppression capacitor 1μF 250V dc wkg (Fig 4)	Suppression capacitor secured by earth terminal and ignition coil fixing bolt.
Charging system			
DC generator (dynamo)	Suppression capacitor 1-3μF 150-250V dc wkg (Fig 11)	Feedthrough suppression capacitor 1μF 250V dc wkg (Fig 11)	Fit close to "D" or output terminal of generator.
Alternator	Suppression capacitor 1-3μF 150-250V dc wkg (Fig 10)	None usually required	Fit in recess provided on slip-ring end casting. Connect between "+" output terminal and earth.
Control boxes for dc generators			
RB106-2	Filter unit	None usually required	Filter units available only from manufacturer of control box.
RB310	Filter unit	Special order only from manufacturer	
RB340	Filter unit		
Electronic regulators for alternators			All electronic regulators incorporate some degree of rf suppression.
Types built-in to alternator	Suppression capacitor 1-3μF 150-250V dc wkg (Fig 10)	None required	Fit in recess provided on slip-ring end casting. Connect between "+" output terminal and earth.
Externally mounted types	Suppression capacitor 1μF	None required	Connect across "+" and "—" regulator terminals. Fit short earth lead to "—" terminal.
Screen wipers			
Permanent magnet field	Suppression capacitor(s) 1μF (Fig 7)	Ferrite-cored inductors 30μH 7A (Fig 7)	Inductors fitted in supply leads. Capacitors connected between brushes and earth.
Wound field	Suppression capacitor(s) 1μF	Ferrite-cored inductors 10μH 3A	For frequencies up to 30MHz earthing straps may be required on motor body assembly.

Equipment to be suppressed	Suppression components Up to 30MHz	30-400MHz	Comments
Electric clocks (continuously driven types)	Suppression capacitor 1μF (Fig 9)	Ferrite-cored inductor 10μH 3A (Fig 9)	Fit components close to clock supply terminal: capacitor in parallel and inductor in series with clock.
Screen washer (pm field)	Suppression capacitor 1μF (Fig 12)—if required	Ferrite-cored inductors 10μH 3A (Fig 12)	Fit components close to motor terminals, capacitor in parallel and inductors (usually two) in series with motor.
Heater fan motor	Suppression capacitors 1μF (Fig 5)	Ferrite-cored inductors 30μH 7A (Fig 5)	Fit components close to motor terminals; inductors (usually two) in series with motor and capacitors between brushes and earth.
Instrument voltage stabilizer	Suppression capacitor 1μF and/or inductor 200μH 0·5A (Fig 6)	Ferrite-cored inductors 10μH 3A (Fig 6) and 5,000pF (maximum) capacitor	1μF suppression capacitor is connected between "B" terminal and earth, and inductors in "B" and "I" leads. The 5,000pF capacitor is connected across stabilizer contacts.
Oil pressure transducer	Ferrite-cored inductor 200μH 0·5A and (if required) a 0·2μF capacitor (Fig 8)	Ferrite-cored inductor 10μH 3A (Fig 8)	Fit components close to transducer terminals, inductor in series and capacitor in parallel with transducer.
Petrol pump			
Solenoid types	Suppression capacitor 1μF	None usually required	Fit capacitor close to pump supply terminal.
Immersed, motor driven	None usually required	Ferrite-cored inductors 30μH 7A (Fig 5)	Inductors connected in each supply lead and close to motor.
Petrol injection pump motor	Suppression capacitors 1μF (Fig 5)	Ferrite-cored inductors 30μH 7A (Fig 5)	Fit components close to motor terminals, inductors in each supply lead and capacitors between brushes and earth.
Other electrical equipment			
Starter, Horn, Flasher unit, Switches	None usually required	None usually required	Suppression of items listed not usually attempted due to their low duty requirements.
Non-electrical items			
Bonnet, Engine block, Gearbox, Exhaust pipe, Rear suspension, Front suspension (two units)	Braided earth straps	Braided earth straps	It is recommended that all the metal parts of a motor vehicle body are bonded together, ensuring good metal-to-metal connections. Thus interference may be reduced by bonding the bonnet and engine block to the bulkhead, gearbox and exhaust pipe to chassis, and the front suspension (both side units) and rear suspension (rear axle) to suitable points on the vehicle body.

found use where vhf and uhf communication equipment is carried on the vehicle as well as being extensively employed to meet legislative limits. Its low resistance is usually a disadvantage for suppression of interference at frequencies in the long and medium wave and hf bands, when it is necessary to introduce some additional impedance in the form of composite carbon suppressor units at the sparking plugs and distributor ht outlets. The suppressed distributor rotor arm has an inductively-wound resistor mounted in the rotor moulding so that it is electrically in series with each distributor spark gap in turn during rotation. The suppressed rotor arm is used in conjunction with resistive cables to obtain improved suppression of vhf and hf interference emanating from the ignition distributor. However, neither is generally available in the UK.

Ancillary equipment

Figs 5-13 show the suppression components it may be necessary to fit to various items of ancillary electrical equipment if both hf and vhf communication equipment is to be operated from the same vehicle. If either hf or vhf equipment only is to be operated from the vehicle, then not all the suppression components indicated in each figure will be required. Instead, it will be necessary to fit only those components which provide the appropriate hf or vhf suppression as specified in the table.

Suppression techniques used for electric motor-driven equipment are illustrated in Figs 5, 7, 9 and 12, and those for alternators and dynamos in Figs 10 and 11 respectively. Alternators having in-built electronic circuits rarely cause interference problems at vhf, although there may be diode

commutation and regulator noise over the frequency range 0·15-10MHz. Diode commutation noise may also be present in the audio frequency range. The suppression arrangement shown in Fig 10 takes account of these eventualities, attenuating any interference at the above frequencies that may enter intermediate and audio frequency stages of a receiver by one or other of the routes suggested earlier.

Figs 6 and 8 show methods of suppressing such contact-operated devices as instrument voltage stabilizers and oil pressure transducers.

All inductors and capacitors used for suppression purposes should be connected as near to the source of interference as possible. In particular the leads of capacitors must be kept very short in order to keep the resonant frequencies of capacitor circuits as high as possible (Fig 17) and thereby obtain the best possible attenuation. The value of a feed-through capacitor for vhf and uhf suppression as opposed to a shunt type can be seen in Fig 17 where their frequency characteristics are compared. Each capacitor has a value of 1μF. □

A simple magnetic base

by R. S. MCMILLAN, GM8JUY*

AFTER the author had obtained a mobile licence, the need soon arose for an effective 2m aerial for his company-owned vehicle. This aerial had to be secure, vandal-proof, easily and quickly fitted and, above all, reasonably cheap.

An old 10in speaker (of unknown age) was to hand, and after dismantling it there seemed very little work required to convert it to a functional magnetic base. Various experiments were tried with the bare magnet but the holding power was very low.

The original pole piece was approximately $\frac{3}{8}$in longer than the magnet itself; see Fig 1(a). This extra length had to be removed, and this was accomplished by sawing through the pole piece a little above the level of the magnet and then, with the magnet in place, filing down the pole piece until the file touched the magnet all the way around. The magnet was then removed and the pole piece dressed off smooth.

Because the original retaining screws were steel and therefore magnetic, these were discarded in favour of brass BA screws. As can be seen in Fig 1(b), the bolts were fitted with their heads inside the magnet in the rough slot for the original bolts. The magnet is a rough casting and these slots are far from smooth or even. This is fortunately just what is required, because the bolt heads fit tightly against the magnet when pulled through the end plate by the lock nuts (Fig 2), thus holding the device together.

At this point the construction of the base was tested by an attempt to separate the magnet and the back plate. This could not be done and it was therefore felt that the base would stand the strain of an aerial.

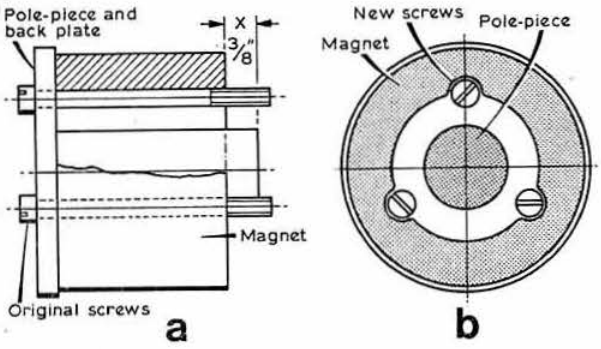

Fig 1. (a) Original magnet and pole piece assembly and (b) position of the new screws

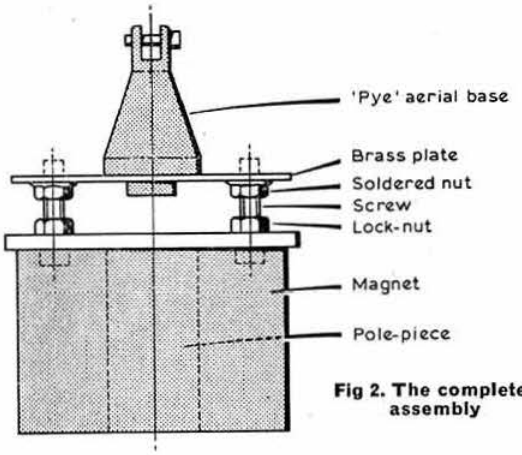

Fig 2. The completed assembly

The next step was to cut a brass (or steel) plate of the same diameter as the back plate. This was drilled to fit the three brass BA screws. A hole was also drilled exactly in the centre for the aerial base insulator. A brass nut was run down each of the three screws and the brass plate was lowered on to them. The three nuts were then adjusted to give the required clearance under the plate. In the author's case this was $\frac{1}{8}$in below the lowest part of the aerial base assembly but it does depend on the aerial base used.

The nuts were then soldered to the brass plate and the screws cut off flush with the top of the plate. This gave a rigid and effective magnetic base, but one which was unfortunately open to the elements. The solution to this problem was to cover the bottom of the assembly with an old balloon, the neck of which had been cut off, and to stretch it tight over the magnet. The top was sealed using the rubber "boot" which covers the drive-shaft joint of BLMC 1100 cars. This was a stretch fit over both the aerial base and the magnet, and no retaining device was required to keep it in place.

The magnetic base has been in use for some time now and has given no trouble at all. It will carry a λ/4 or λ/2 whip and has been tested at speeds of up to 85mile/h with no detrimental effects being found. It will not, however, withstand the "whip" effect of a 5λ/8 loaded aerial. Since all components except the rubber boot were to hand, the total cost was less than £1.

On-the-air tests have shown no difference between this aerial and an ordinary aerial fitted into the roof, and it shows greatly improved radiation compared to a λ/2 aerial mounted on the rear wing of a BLMC 1100 car. □

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